

Constellation X

The Constellation X-ray Mission



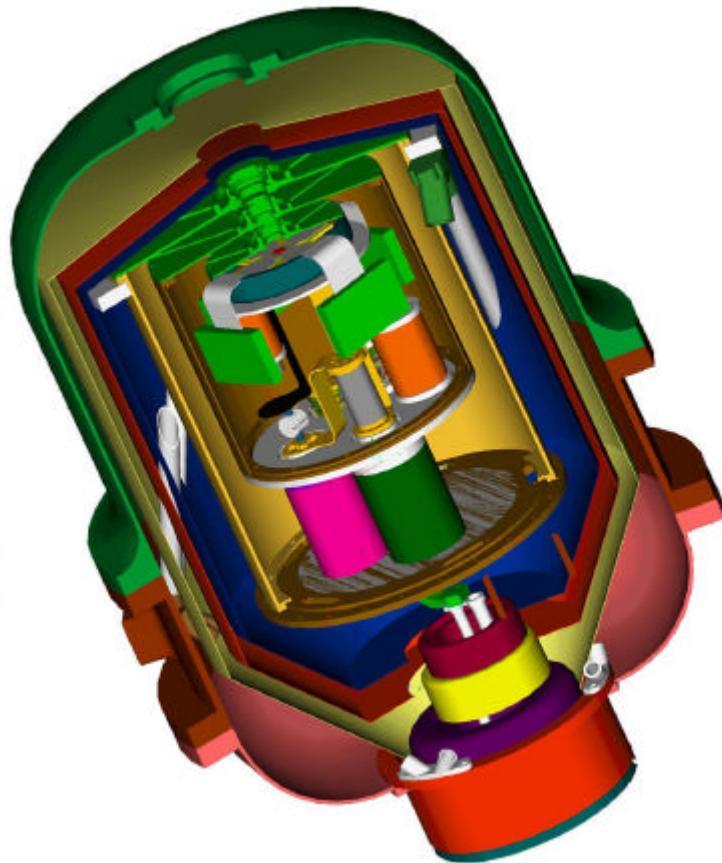
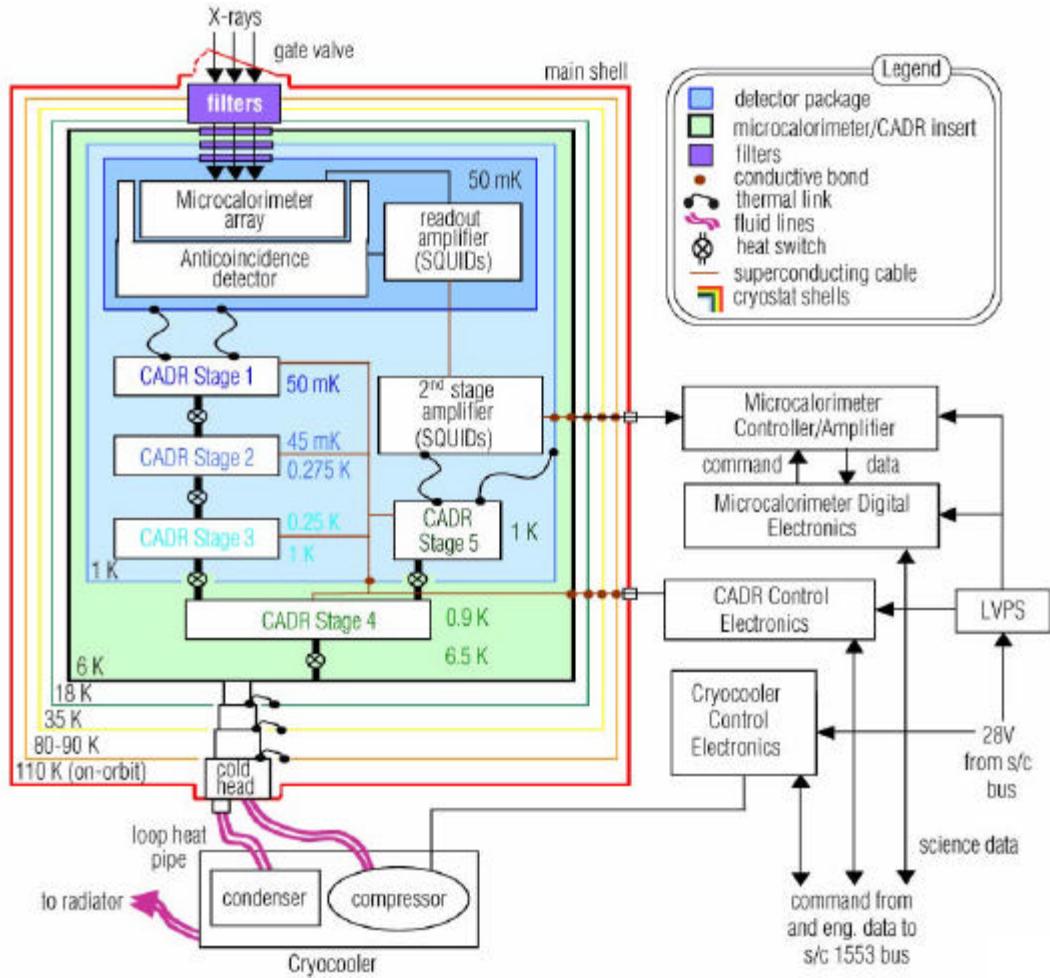
► X-ray Microcalorimeter Spectrometer (XMS)

*Richard Kelley
Goddard Space Flight Center*

Calorimeter Agenda

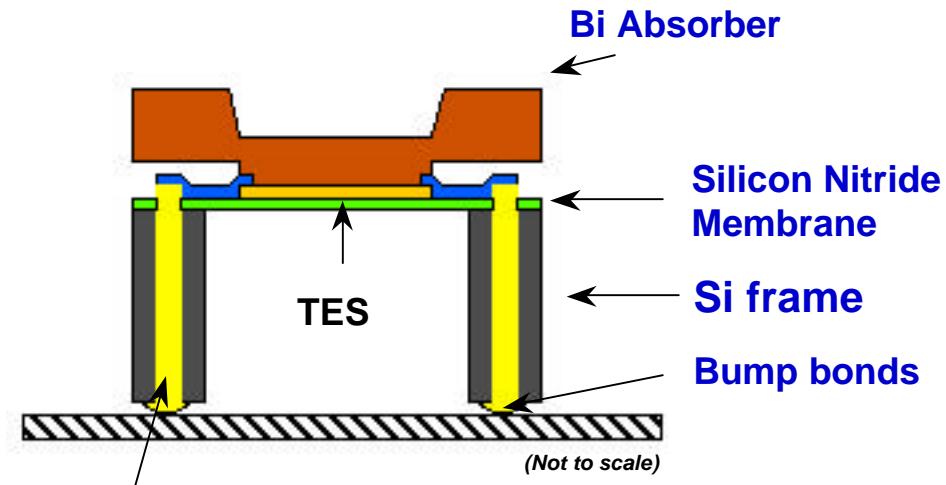
- XMS Agenda and Overview - Kelley, 5 min
- Progress on NTD Microcalorimeters - Silver, 10 min
- Progress on TES Microcalorimeters - Stahle, Irwin, 20 min
- *Guest Report:* Recent Results on Magnetic Calorimeters - Enss, 5 min
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- Extending microcalorimeter capabilities to lower energies - Kelley, 20 min

Instrument Block Diagram and Conceptual Implementation

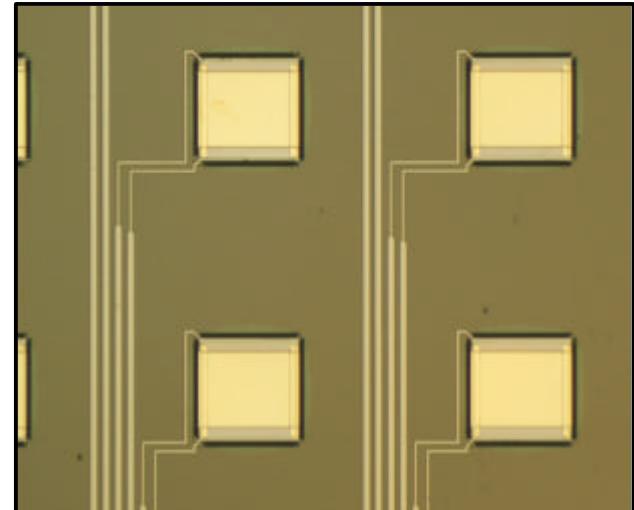


Size ~ 50 x 75 cm
Mass ~ 150 kg, including electronics

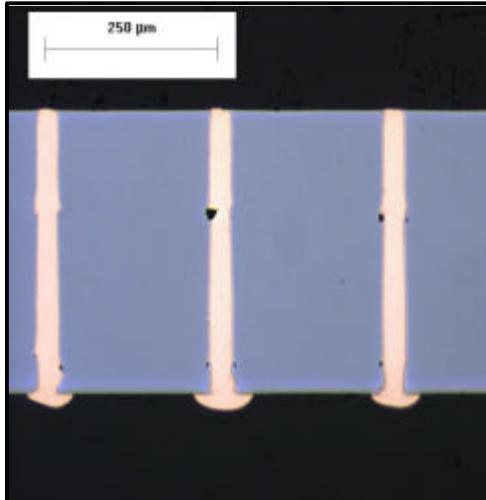
Reference Array Concept



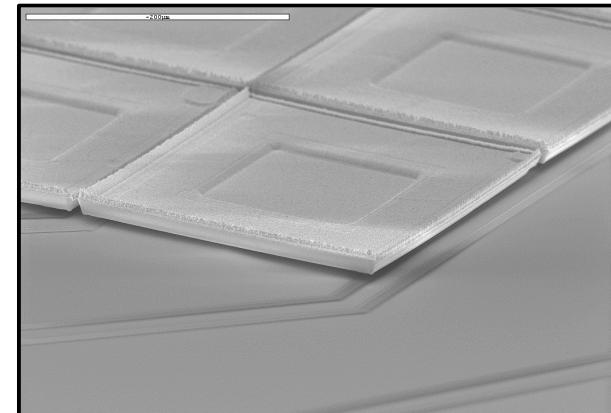
Through-wafer microvias



Array of identical TES devices

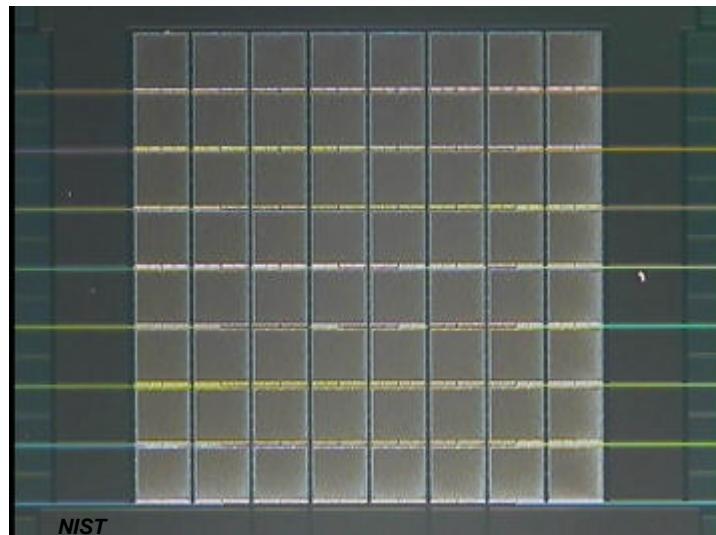
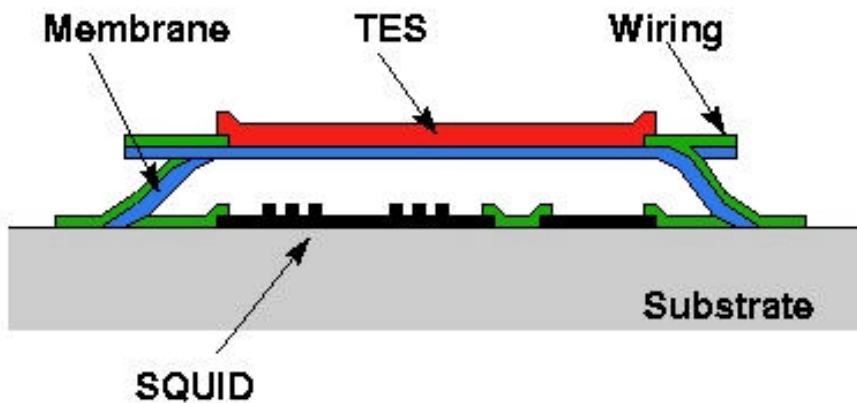


Cu microvias in Si (25 x 425 microns)



Integral, overhanging Bi absorbers developed at Goddard for this project

Alternate Technology: Surface Micromachining

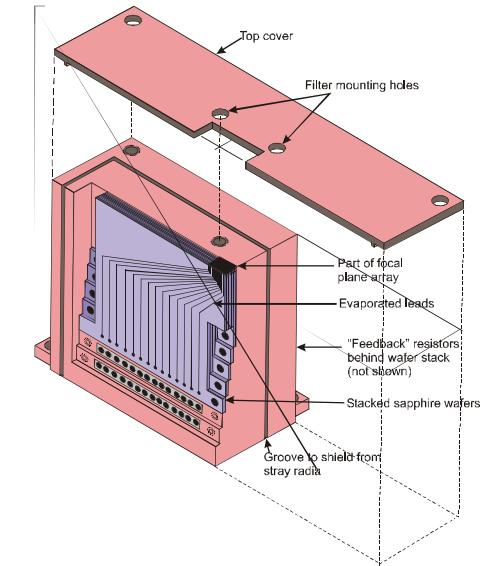
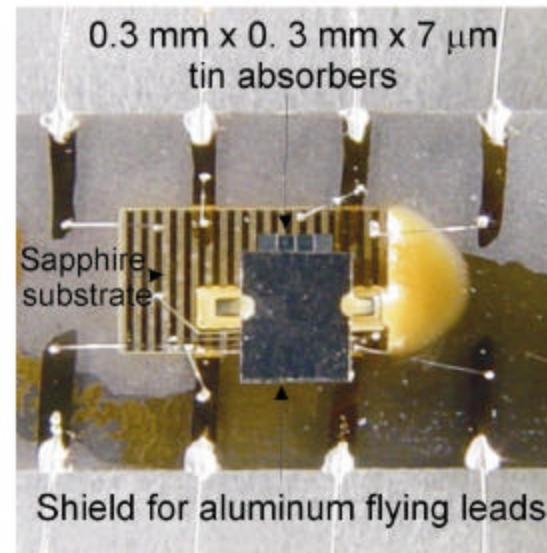
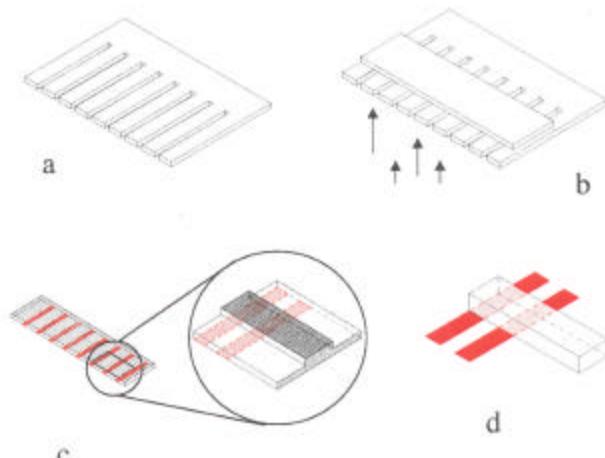


8 x 8 Attay Produced at NIST

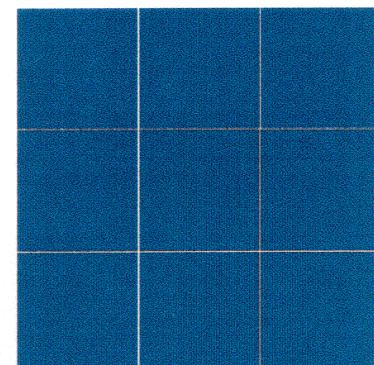
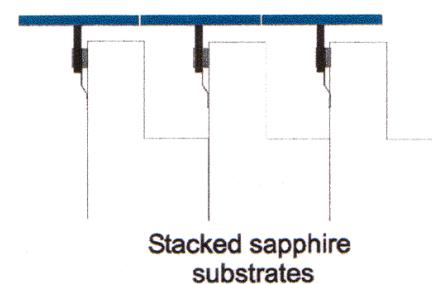
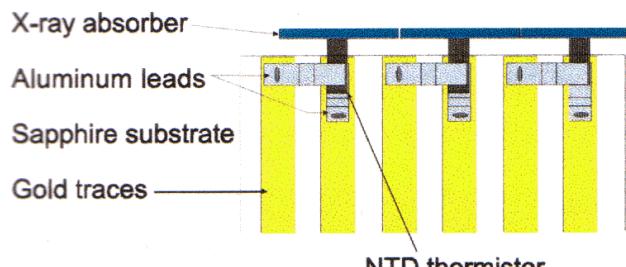
- Demonstrated superconducting Mo wires running up on platform (to connect pixels)
- Demonstrated superconducting Nb wires running beneath platform (to extract leads from focal plane)

Alternate Technology: NTD Ge Calorimeter

Prototype 1 x 4 NTD Germanium Microcalorimeter array



Schematic representation of a 3 x 3 array



Front View

Side View

Top View

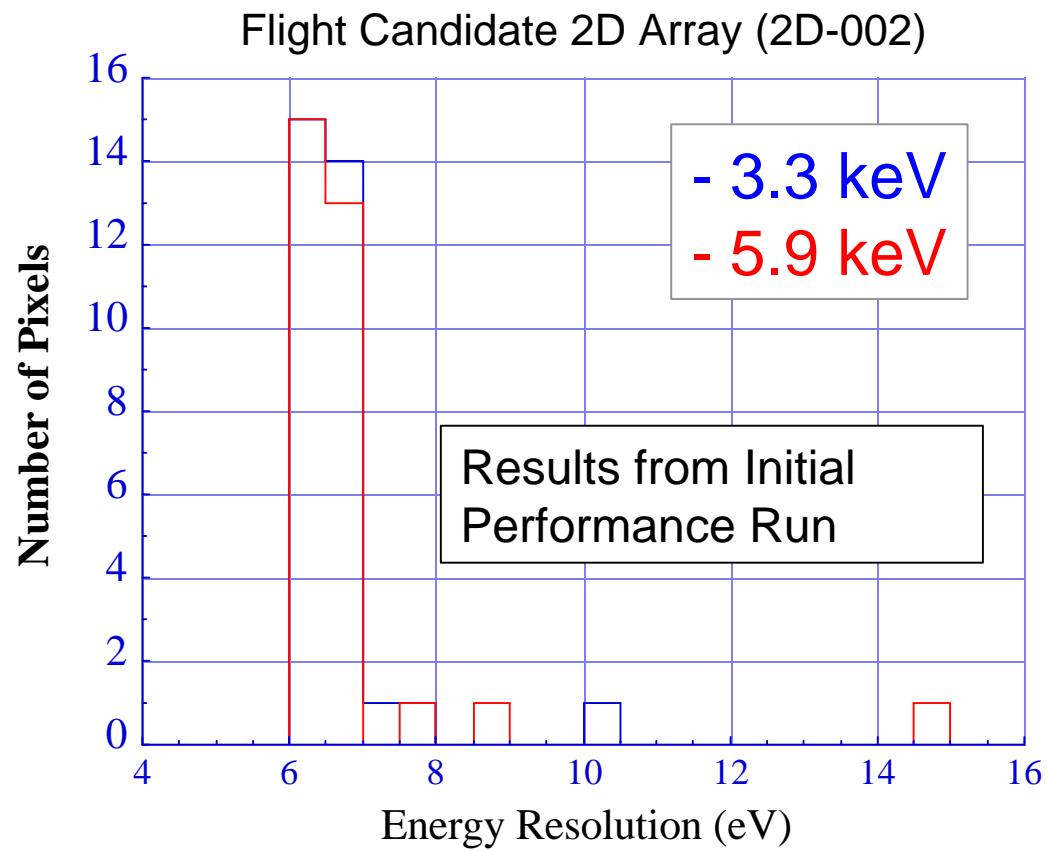
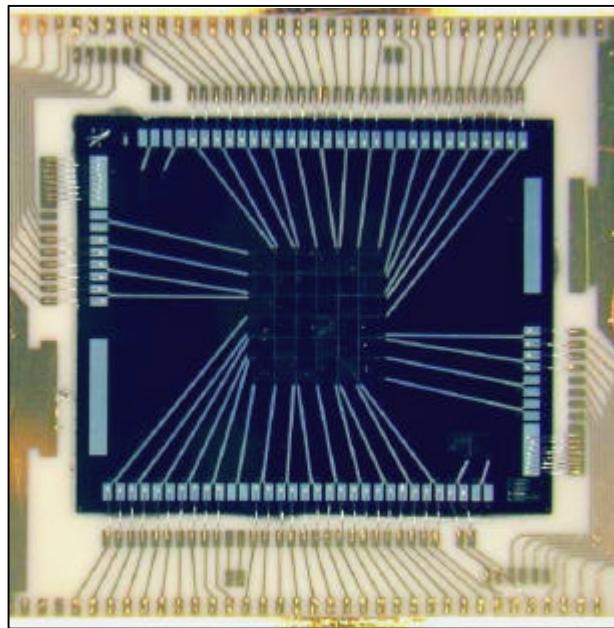
Another Technology: Ion-implanted Si

32 pixel elements
625 micron pixels

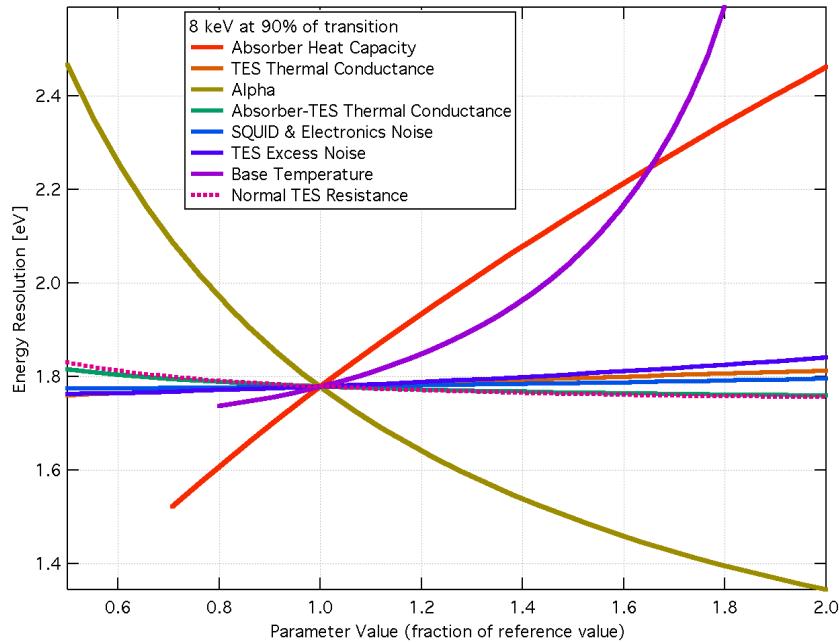
Energy Resolution @ 6 keV:

6 eV at 60 mK

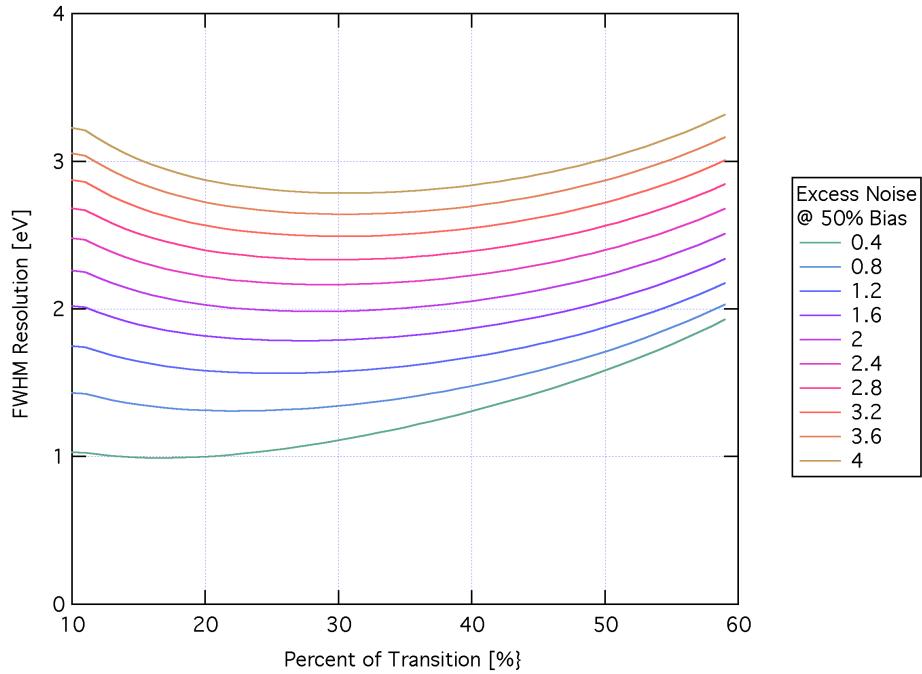
4.8 eV @ 50 mK



Energy Resolution Sensitivity Analysis



Energy Resolution as a function of normalized variations in the design parameter values. Note that any deviation from the reference involves changes not only in the energy resolution but in the energy bandwidth and count rate.



Energy Resolution versus operating point in superconducting transition for different levels of excess noise.

Microcalorimeter Technology Roadmap

Element	State-of-the-Art	Array TRL 4	Readout TRL 4	TRL 5	TRL 6	Flight Requirement
Array Size	32	5 x 5	24 pixels on 4 chips	8 x 8	32 x 32	32 x 32
Channels read out simultaneously	32	4	24	16	96	1024
Fabrication				Reliable superconducting leads, parasitic R < 5% of normal R	High-density microvias and bump-bonds	
MUX Scale	None	None	2 x 12	2 x 8	3 x 32 goal	32 x 32 goal
MUX Speed	None	None	5 MHz	10 MHz	20 MHz	20 MHz
Pixel Size	0.64 mm	0.25 mm	0.4 mm	0.25 mm	0.25 mm	0.25 mm
System Noise				< 2 eV	< 1 eV	< 1 eV
Energy Resolution	4.8 eV @ 6 keV	10 eV @ 6 keV			4 eV @ 6 keV	
Testing					Radiation, Environmental	
Time frame	XRS	Q1 of FY03	Q1 of FY03	Q4 of FY04	Q4 of FY05	
Technology gates				

Calorimeter Agenda

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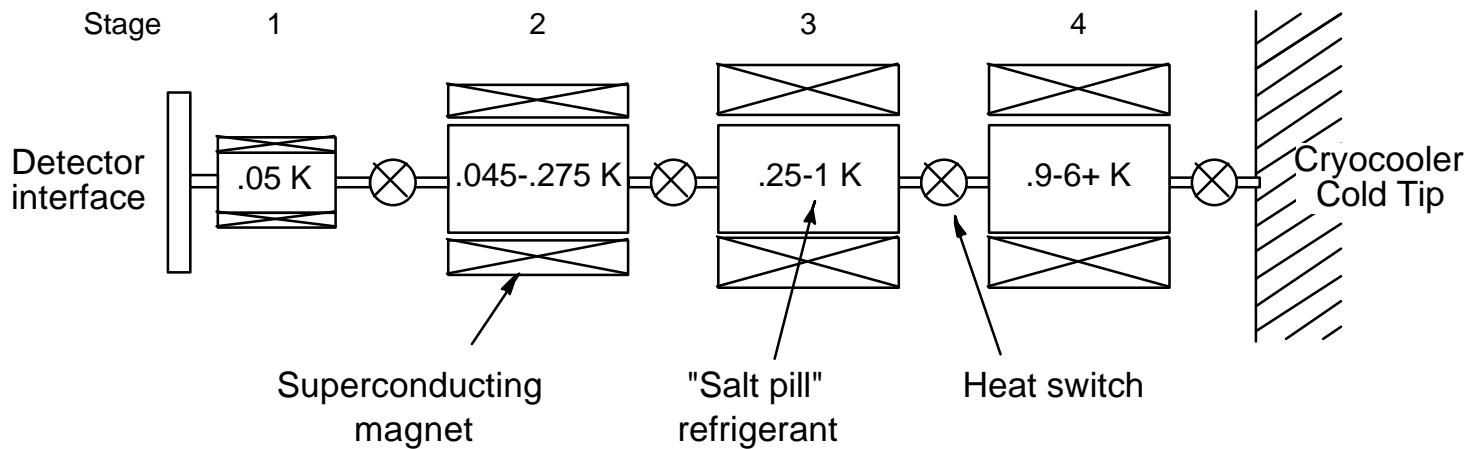


► X-ray Microcalorimeter Spectrometer (XMS) CADR

*Peter Shirron
Goddard Space Flight Center*

CADR Concept and Requirements

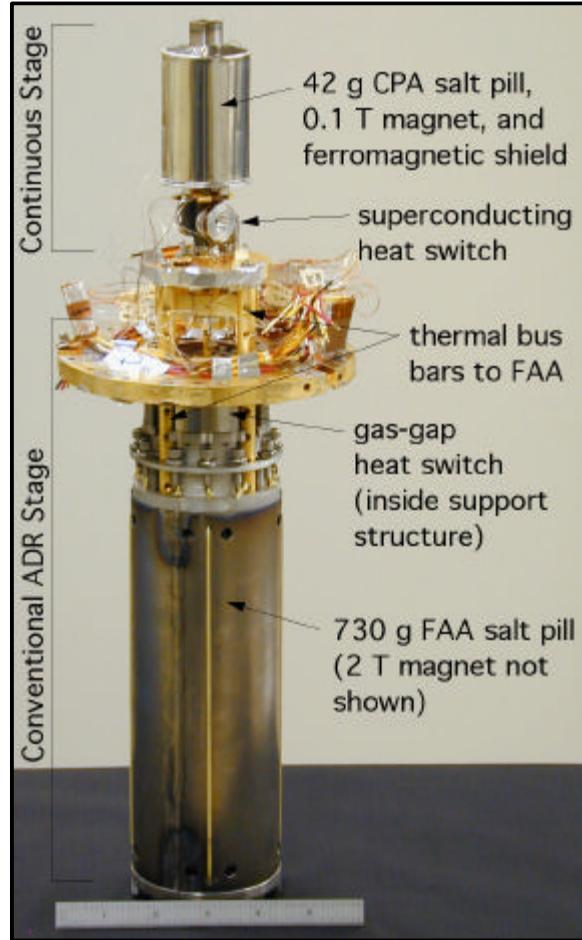
Cooling Stage	Temperature	Cooling Power	Temperature Stability	Heat Rejection Temperature
Detectors, 1st stage SQUIDs	50 mK	5 μ W	2 μ K rms	6 K
2nd stage SQUIDs	1-4 K	230 μ W	TBD	



- **Operation**
 - First stage regulates load at desired temperature
 - Upper stages cascade heat to the cryocooler
- **Fifth stage will provide stable “1 K”**

CADR Demonstration Units

2-stage
(9/00-12/00)



Heat transfer at 50 mK

3-stage CADR
(6/01-12/01)



First demonstration of continuous cooling

- 35-100 mK operation
- 1.3 K helium bath

4-stage CADR
(7/02-present)

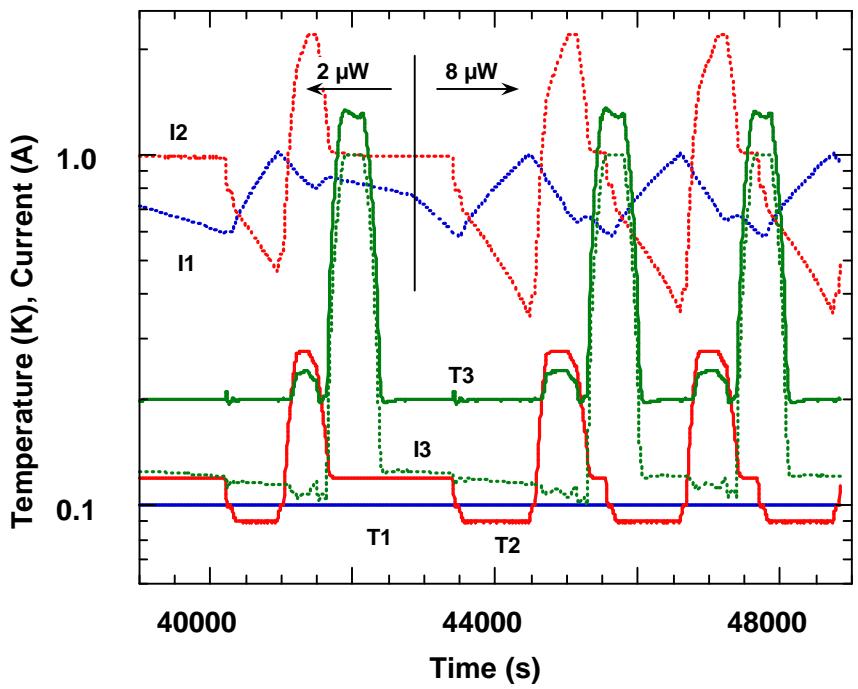


Demonstrates functionality needed for Constellation-X

- High cooling power
- High efficiency
- High heat rejection (4.2K)

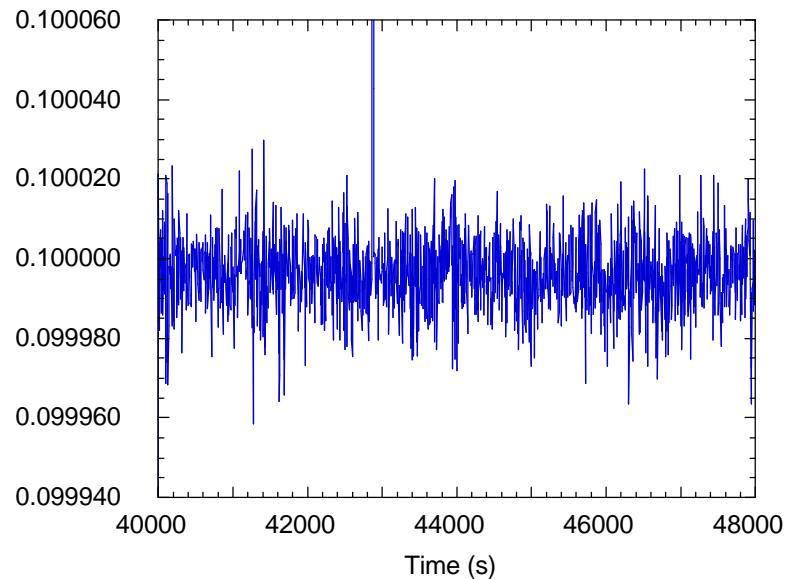
CADR Performance

- Control is fully automated
 - Including initial cool down



T (K)	Cooling Power (μ W)
0.10	21
0.09	18
0.08	15
0.07	12
0.06	9
0.05	6

8 μ K rms stability limited by readout electronics



CADR Technology Roadmap

Element	TRL 3	TRL 4	TRL 5	TRL 6	Flight Baseline
Number of stages	3	4	4	5	5
Heat rejection temperature	1.3 K	4.2 K	6 K	6 K	6 K
Operating temperatures	60 mK	50 mK	50 mK	50 mK/1-4 K	50 mK/1-4 K
Cooling power at 50 mK		6 mW	> 6 mW	> 6 mW	5 mW
Cooling power of "1K" stage				> 0.3 mW at 1 K	0.23 mW
Temperature stability		8 mK rms at 100 mK	8 mK rms at 50 mK	2 mK rms at 50 mK	2 mK rms above 1 Hz
Technology goal		High-temperature refrigerants	6+ K magnets	Flight electronics	
Testing				Env. Testing, XMS-level testing	
Time frame	FY01	FY02	Q4 of FY05	Q3 of FY06	
Technology Gates			◆		

Coming this summer...

New 4th stage operating to sink at 4.2 K.

A 10 K Nb3Sn magnet ready soon for summer integration into test dewar with lab *Gifford-McMahon* cooler as heat sink.

^3He passive gas gap heat switch technology developed with adjustable operating temperatures.

A 4 K version operating with new 4th stage with testing underway on 1 K version for use with 3rd stage.

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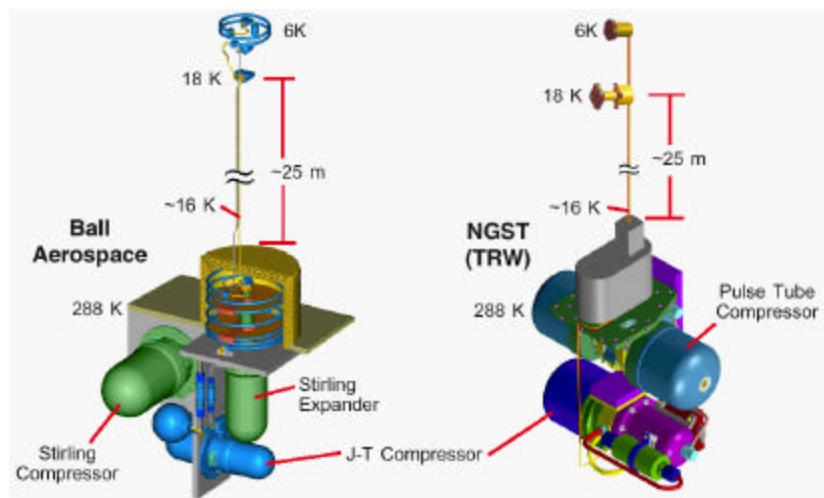
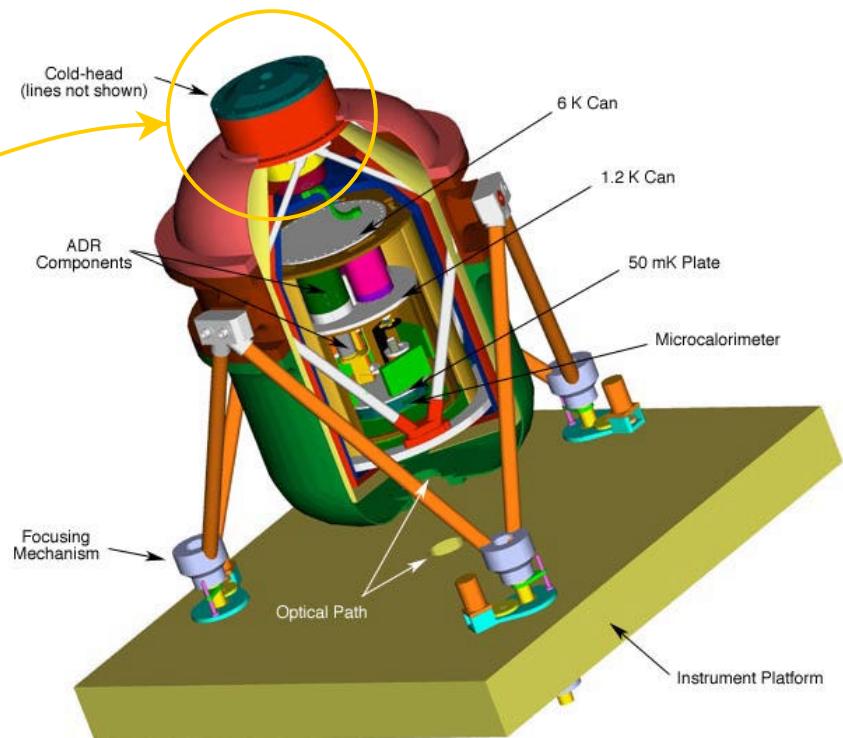
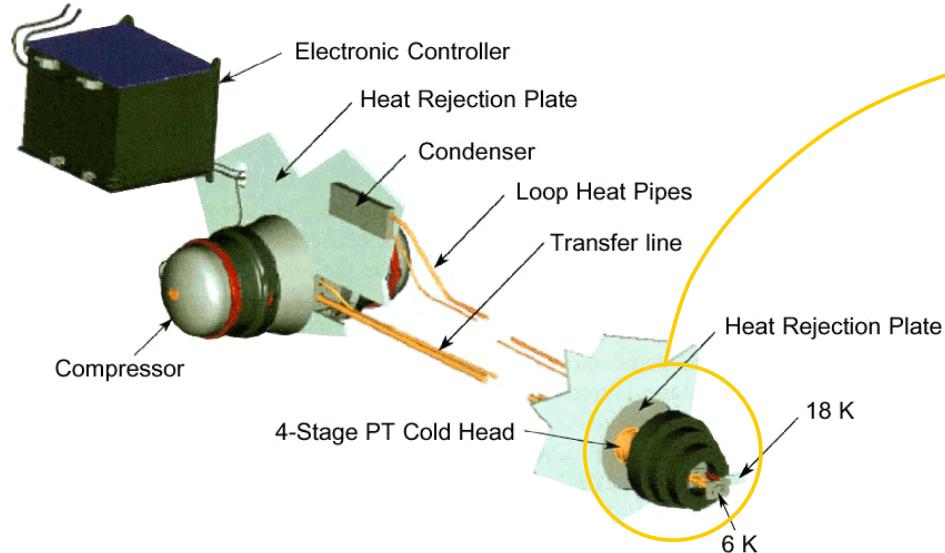
► X-ray Microcalorimeter Spectrometer (XMS) Cryocooler

*Paul Whitehouse
Goddard Space Flight Center*

Cryocooler Development

- Advanced Cryocooler Technology Development Program (ACTDP)
 - OSS-funded through Terrestrial Planet Finder program, but joint program with Constellation-X and JWST
 - One year of risk retirement
 - Build of 4-stage TRL-5 pulse tube cryocooler
 - Lockheed pulse tube cooler geared toward Constellation-X
 - 6 K cooling demonstrated with Lockheed 3-stage pulse tube
- Constellation-X
 - Carry to TRL-6
 - Plan for new cold-head to meet final EM cryostat loads
 - Integrate with Microcalorimeter and ADR in EM cryostat = EM XMS

ACTDP Cryocooler and XMS



Cryocooler Developments:

BALL and NGST (TRW) have signed contracts for the demo phase of the ACTDP. Kick-offs on May 14 and 21, respectively.

Lockheed to sign off soon; kick-off expected in early June.

One year to demonstrate certain capabilities identified as risk items.

Another year to build TRL-5 cryocooler.

Cryocooler Roadmap

Element	State-of-the-Art	TRL 4	TRL 5	TRL 6	Flight Baseline
Compressor power	120 W	Similar design operating at 240 W	EM at 200 W		200 W
Pulse tube cold head	1 W at 57 K	Multi-stage lab test w/GSE compressor 20 mW at 6 K	EM w/GSE compressor		20 mW at 6 K 150 mW at 18 K
Control and drive electronics		Brassboard of ripple suppression	Single-box control, power, and ripple suppression		
Testing			Component vibe testing, System functional and TV testing	System level EMI test	
Time frame	TES & AIRS flight coolers	FY02	Q3 of FY05	Q3 of FY06	
Technology Gates			◆		

Question 7 (5 of 5): XMS Cryostat Heat Map

